

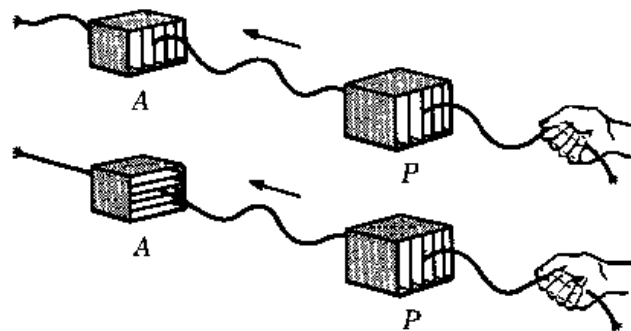
Polarization

Light is a transverse electromagnetic wave. That means that the direction of the electric field is perpendicular to the direction that the wave is moving, just as the shaking of a rope wave is perpendicular to the direction of the rope.

Electromagnetic waves, like rope waves, are polarized. If the electric field is in the vertical direction, we say the wave is vertically polarized. It can also be horizontally polarized. By convention, any other direction of polarization is seen as a combination of vertical and horizontal. For example, a wave polarized at 45 degrees from the horizontal can simply be said to be oscillating in the vertical and horizontal directions at the same time.

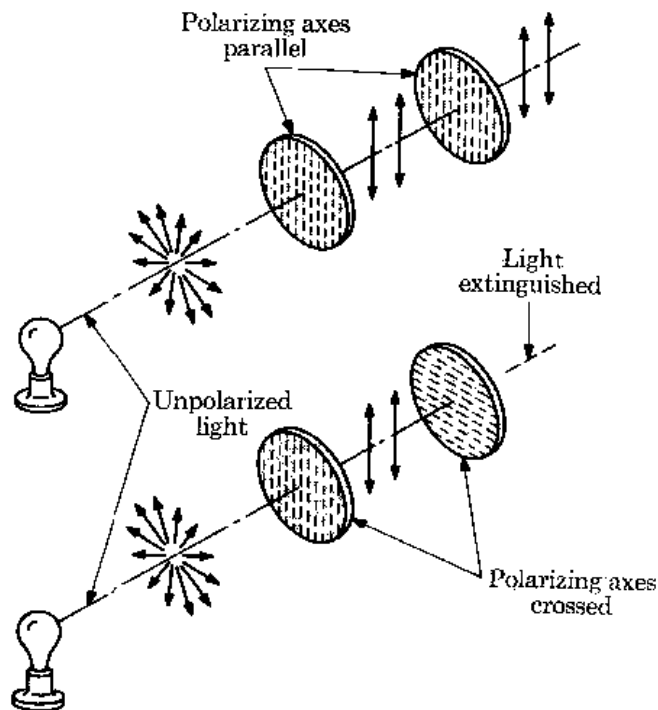
Polarization has become extremely important in modern technology. Liquid crystal displays (used on computer and TV screens) are based on switchable polarizers (we'll discuss this soon). Polarization all gives us a fascinating insight into materials, rocks, and microscopic creatures. We'll discuss these applications in a moment.

Ordinary light (from a light bulb, from the sun) usually consists of many different waves all coming at the same time. As light comes from different atoms in the source, each little part of the wave can have a different polarization. Such light is said to be "unpolarized." The light can be made to have a single polarization by passing it through a material called a polarizer. To understand this it is useful to think about rope waves passing through a picket fence. In the diagrams below, the fence will pass only waves that are polarized in the matching orientation.



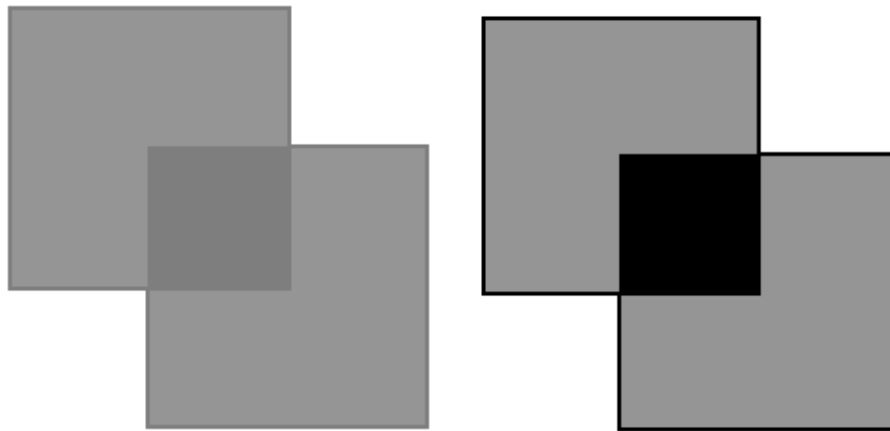
borrowed from <http://www.lhup.edu/~dsimanek/scenario/analogy.htm>

Thin films that do the same thing were invented by Edwin Land, and trademarked under the name "polaroid". (The Polaroid company later made cameras, but their initial work was solely polaroids.) Polaroid films are also used today in sunglasses. As with the ropes, the film passes only one kind of polarization at a time, as shown in the diagram below.



borrowed from <http://www.lhup.edu/~dsimanek/scenario/analogy.htm>

Unpolarized light, when it passes through a polaroid, emerges polarized. If it then hits a second polaroid, it will pass through – provided the polaroid is oriented in the same direction. If the second polaroid is oriented perpendicular to the first, then the light is stopped. This is illustrated in the diagram below.



In the left figure, the two polaroids are both vertical. In the right figure, the top one is vertical and the bottom one is horizontal.

borrowed from <http://www.lhup.edu/~dsimanek/scenario/analogy.htm>

polaroid sunglasses

There are other ways to polarize light. When light bounces off the surface of glass or water or even asphalt (and other non-metals) then the light tends to become polarized in the horizontal direction. If you are fishing, and want to see into the water, and you don't want to be distracted by light reflecting off the surface of the water, then you can take advantage of the fact that the bouncing light is polarized. Wear sunglasses made out of polaroid film, with the film oriented such that it will pass only vertically-polarized light. Then it will stop the reflected light, but half of the light coming from the fish will still be visible.

Polaroid sunglasses advertise that they "cut glare." What they really cut is light that has been reflected off non-metal surfaces. When light bounces off a metal it does not become polarized, so such sunglasses don't help for that kind of glare.

crossed polarizers

When light passes through a transparent material such as plastic, then internal (and normally invisible) stresses in the material can rotate the angle of polarization. Moreover, different colors will be rotated by different amounts. If a horizontal polarizer is placed below the object, and a vertical one is above it, then no light will be transmitted unless there are stresses inside the object that rotate the light. This effect is seen in the image below.



borrowed from Hewitt:

http://www.arborsci.com/Products_Pages/Light&Color/Light&Color7.htm

This effect can be useful in the design of engineering structures. You build a model out of plastic, and view it with crossed polarizers. Then you put a force on the model. The regions of the model that are stressed the most will show up in color. This way you can determine which parts of the structure are most likely to break, and the design can be changed (if necessary) to relieve some of that stress.

liquid crystals

Liquid crystals are materials which act like polaroid film, except that their ability to polarize can be turned on and off with an electric voltage. If you have crossed polarizers, and one is a liquid crystal, then the amount of light coming through can be changed with an electronic signal.

Many thin-screen computer displays take advantage of this. The term “LCD” refers to “liquid crystal display.” Laptop computer displays are usually liquid crystal displays with fluorescent lights behind them. If the polarizers are completely crossed, then no light gets through. If they are parallel, then the maximum light comes through. If they are oriented (electronically, remember) at 45 degrees, then half of the light comes through.